The HIPE Theory of Function

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Abstract

We propose that function is a complex relational concept that draws on many conceptual domains for its content. According to the HIPE theory, these domains include History, Intentional perspective, the Physical environment, and Event sequences. The function of a particular entity does not have a single sense. Instead many different senses can be constructed that depend on the conceptualizer's current goal, setting, and personal history. On a given occasion, relevant knowledge is assembled across conceptual domains to construct a relevant sense, represented as a mental simulation and structured by a causal chain.

Function

The role that an entity plays in serving the goal of an agent, or its role in the operation of a larger system such as a geology, ecology, or religion.

9.1 Introduction

Although function is a central construct across the cognitive sciences and neurosciences, its detailed structure has received little attention (but see Wimsatt, 1972; Wright, 1973).1 Often an entity’s function is viewed as a single unanalyzed

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1 These articles were brought to our attention after developing the HIPE theory and writing this chapter. Although these authors had different aims than ours, they made similar points and reached similar conclusions.
property. In many theories, a function is just another amodal symbol abstracted from perception and action. When functional properties are viewed modally, they are often assigned to a single modality, namely, the motor system.

We propose that function is a much more elaborate construct. First, a function is a complex relational structure, not a single unanalyzed property. Second, the complex relational structure that represents a function is distributed across many modalities, not just one. Third, there is not just one sense of an entity’s function, there are many.

The HIPE theory is an account of people’s knowledge about function. It describes the content of this knowledge and how it is used, both for artifacts and natural kinds. The HIPE theory is not an account of the physical world. Although functional knowledge may often correspond to the world, significant departures arise (e.g. the roles and essences described later for history). Also we do not view functional knowledge as an independent module in the brain. Rather functional knowledge emerges as people integrate information across diverse conceptual domains. In general, HIPE provides an analysis of how functional knowledge is represented and processed.

We will assume that mental simulations represent the complex relational knowledge in functions. By mental simulation we mean reenactments of experience in sensory-motor systems, similar to mental imagery. See Barsalou (1999) for further discussion of theory, and Barsalou (2003) for empirical evidence. As will become clear, we further assume that causal chains underlie function (e.g. Glymour, 2001; Pearl, 2000; also see Sloman, Love, and Ahn, 1998), with causal relations producing transitions between states of functional simulations. For a review of HIPE’s relation to the literatures on function, see Chaigneau and Barsalou (in press). For empirical tests of HIPE, see Chaigneau (2002) and Chaigneau, Barsalou, and Zamani (2004).

9.2 The HIPE Theory

HIPE specifies that representations of function integrate four types of conceptual knowledge: History, Intentional perspective, Physical environment, and Event sequences. Table 9.1 summarizes the relevant knowledge and presents a notation for representing it. In this section, we focus on HIPE’s conceptual content; in the next, we address the causal chains that represent function.

9.2.1 Intentional perspective (I)

When representing an entity’s function, many different senses can be conceived. Just as there is tremendous diversity in how people represent a category (Barsalou, 1987, 1989, 1993), so are there many different ways to represent an entity’s function. An agent’s intentional perspective, I, is the gateway into functional knowledge, with I determining the information retrieved about function on a given occasion. 2

As Table 9.1 illustrates, I includes a meta-cognitive purpose, MP, and a point-of-view, POV. When representing an entity’s function, an agent typically has a meta-cognitive purpose in doing so, namely, the reason why the agent—at the meta-cognitive level—is accessing knowledge about the entity’s function (as opposed to the concrete purpose of actually using the object). For example, an agent may have the goal of establishing the origin of an entity’s function. Under this MP, the agent retrieves a subset of functional knowledge that establishes this origin. On another occasion, the agent may have the goal of identifying physical properties that produce optimal functional outcomes. Under this MP, the agent recalls successful uses of the entity and attempts to identify correlated physical properties. On another occasion, an agent may have the goal of using an entity to achieve its standard function (e.g. using a hammer to pound in a nail). Under this MP, the agent retrieves a procedure for using the entity. Many other MPs are

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2 The notational symbols in the text and Table 9.1 are variables that become bound to values. These symbols do not refer to specific propositions. Thus I does not refer to a particular proposition about an agent’s intention, but is a variable that takes a specific intention as a value.
possible, each retrieving different subsets of functional knowledge. Thus an entity’s function has many senses—not just one—with the current MP determining the relevant sense. In principle, a wide variety of MPs are possible; in practice, a few probably dominate, such as those just described.

In simulating a function, the agent’s MP always leads to a particular point of view, POV. If the agent’s MP is to pound in a nail herself with a hammer, the agent adopts her own POV to guide action. In contrast, imagine that the agent is asked whether her roommate could use a hammer to hang a picture. The MP is still to use a hammer for its standard function. However the simulation of this functional sense now takes the POV of the roommate. Similarly imagine that the agent speculates on why hammers have the function they do. Under this MP, the agent might adopt the POV of an inventor, or perhaps some prehistoric figure making a hammer. Finally imagine that the agent is asked to think about the optimal physical properties to achieve a hammer’s function. Under this MP, the agent may adopt the POV of an omniscient observer looking across the distribution of functional simulations currently accessible. As these examples illustrate, the current MP causally initiates the POV:

$$\text{MP} \rightarrow \text{POV}$$  \hspace{1cm} (1)

Once an MP and a POV are in place, they determine the remaining content of a functional simulation.

9.2.2 History (H)

Researchers have argued recently that history is central to an object’s function (e.g., Bloom, 1996, 1998; Gelman and Bloom, 2000; Matan and Carey, 2001; Prasada, 1999a). According to these views, people believe that an object’s physical structure depends on the original purpose it was intended to serve at the time of its creation—the design stance. As Table 9.1 illustrates, history, H, has a parallel structure for artifacts and natural kinds that differs in their respective realizations. For artifacts, H includes a role, R, an invention process, IV, a manufacturing process, M, and a use history, UH. The role, R, is the purpose that the artifact was originally intended to serve at the time of its invention, IV. Thus cars were created for transportation, and telephones for communication. Specific instances of the artifact are created during a manufacturing process, M, and then acquire a particular use history, UH, once agents acquire them. For example, a particular hammer might only be used as a paper weight. As a result, this non-standard function may dominate the hammer’s use history, thereby obscuring its standard role, R. Use history is important later when we address non-intended uses of entities, such as ad hoc categories (Barsalou, 1983, 1985, 1991).

Whereas R and IV together constitute the long-term history of an artifact category, M and UH together constitute the immediate history of an instance.

An agent may not know all of the long-term and immediate history for an artifact, and what they know may be incorrect. Even when knowledge is non-optimal, however, agents are likely to know that R, IV, M, and UH are relevant at a meta-level (i.e. they know that such knowledge probably exists and is relevant). Most importantly, agents believe that an artifact’s long- and short-term histories are central to its function.

For natural kinds, H has a parallel structure. A given natural kind category plays a role, R, in an ecology. Thus plants provide food for animals, and fertilize for other plants. Animals control other populations of animals, clean the environment through scavenging, fertilize plants, and so forth. Geological kinds such as water provide sustenance for plants and animals. A natural kind comes to achieve its role, R, through some sort of evolutionary, geological, or religious process, EGR. Individuals who subscribe to scientific thinking may typically believe that the roles of natural kinds arise through evolution and geography, whereas individuals who subscribe to religious thinking may view creationism as important. Specific instances of a natural kind are created in some manner, C, and then acquire a particular life history, LH. For example, plants and animals are created via reproduction and birth, whereas water is created via condensation. Analogous to an artifact having a use history, UH, a natural kind may have a life history, LH, that may depart from its original role, R (e.g. a porcupine that becomes a pet).

Whereas R and EGR together constitute the long-term history of a natural kind, C and LH constitute the immediate history of an instance. An agent may not know all of the history for a natural kind, and what they know may be incorrect. Even when knowledge is non-optimal, however, people are likely to know that R, EGR, C, and LH are relevant at a meta-level. Most importantly, people believe that a natural kind’s long- and short-term histories are central to its function.

We offer several additional proposals about history. First, we assume that simulations represent the content in H. For example, people might simulate the invention or manufacture of an artifact, or they might simulate two animals producing offspring.

Second, historical chains arise in various ways. Sometimes a role exists that leads to the creation of an entity. For example, there may be an historical need for a tool, which eventually leads to its invention and manufacture:

$$R \rightarrow IV \rightarrow M$$  \hspace{1cm} (2)

Alternatively, an inventor may explore a domain and in the process discover a role that consumers never knew had use, although they appreciate it once the manufacturing process creates the product:

$$IV \rightarrow R \rightarrow M$$  \hspace{1cm} (3)

For natural kinds, roles and evolution/geology/religion may be intertwined in such complex ways that it is impossible to determine which came first.
Thus people may often view creation as the outcome of roles coupled with evolution/geology/religion:

\[ R \rightarrow C \]

\[ \text{EGR} \rightarrow \text{C} \]  

(4)

Ultimately how agents represent causal chains to themselves is an empirical question. As these examples illustrate, HiPE can represent a number of possibilities.

Third, we view roles, \( R \), as detached historically from the events in which entities actually perform their functions. An artifact's role is the purpose that its inventor was trying to achieve in designing it originally. A natural kind's role is the purpose that a scientist or religious figure defined it as playing in some theoretical framework. Whereas roles reside in past history, goals and outcomes attempt to realize them in specific functional events.

Finally, roles, goals, and outcomes are closely related, as just described. An agent's goal, \( G \), to use an artifact often corresponds to its historical role, \( R \). Similarly, the outcome of using the artifact, \( O \), hopefully realizes the goal. For example, an agent's goal to pound in a nail with a hammer instantiates the hammer's more general role. Similarly the agent's goal is realized when the intended outcome occurs, namely, the nail is pounded in completely. Thus \( R, G, \) and \( O \) are highly similar, given that they all represent using a hammer to pound something in successfully. Nevertheless, \( R \), \( G \), and \( O \) differ in important ways. As just noted, \( R \) is the role of an artifact in the mind of an inventor or manufacturer. For a natural kind, \( R \) is a role within a scientific or religious framework. In contrast, \( G \) and \( O \) are specific realizations of \( R \) at different points in functional event sequences. A goal is an agent's intention to realize a role on a given occasion, and an outcome is an event that hopefully realizes the goal. Later we will see how alignment between roles, goals, and outcomes in causal chains produces a variety of functional phenomena.

9.2.3 Physical environment (P)

In this section and the next, we turn to the content of a functional event sequence, \( E \), that occurs in the physical environment, \( P \). In HiPE, \( P \) revolves around \( FO \), the focal object whose function is of interest. Nevertheless, other parts of \( P \) are important as well, including relevant aspects of the setting, \( S \), and optionally an external agent, \( EA \). We treat each in turn. Again we assume that simulations represent these components in functional reasoning.

As Table 9.1 illustrates, a focal object has physical structure, \( PS \), and may optionally have internal goals, \( G \). An entity's function obviously depends on its physical structure (e.g. Gibson, 1979a, 1979b). For example, the handle and head of a hammer allow it to function as a hammer but not as a screwdriver. Although people may not view most artifacts as having internal goals, they may believe that some do (e.g. robots, automatic teller machines, car alarms). Animals clearly have internal goals, and plants can be viewed as having related tendencies to thrive, reproduce, and avoid threats. Like most artifacts, geological kinds do not have goals. Under various circumstances, however, artifacts and geological kinds may be imbued with internal forces that enter into causal explanation. Religious history, \( EGR \), may infuse artifacts, geological kinds, and living things with intentionality, and so may people's proclivity to anthropomorphize. Similarly, when people believe that an entity's history implants an essence in its physical structure, the essence may have a goal-like character (e.g. Gelman and Diesendruck, 1999).

Knowledge of background settings, \( S \), typically contributes to understanding the functions of focal objects. Knowing the physical structure of a hammer, for example, is not sufficient for knowing its function. Knowledge about nails and wood is also essential. Similarly, knowing the setting of a tree is necessary for understanding its functional role in the environment. In general, \( S \) includes knowledge about objects and locations central to understanding functions. We do not specify the components of \( S \) here, given that many are possible. For a sense of the variety, see the components of situations in Wu and Barsalou's (2004) coding scheme.

Finally, external agents, \( EA \), are central to understanding the functions of artifacts. We define an \( EA \) as an agent who helps a focal entity achieve a function it cannot achieve on its own. Whereas some entities achieve their functions without external agents, others require them. As just described, animals, plants, and some artifacts have internal goals that drive their behavior towards their historical roles, \( R \). Although these entities are clearly agents, they are not external agents. In contrast, a hammer cannot achieve its function without an external agent using it. Interesting cases arise when agents such as plants and animals become artifacts for humans (e.g. food, transportation, pets). Under these conditions, humans become external agents who contribute to plants and animals developing new functions that differ from their evolutionary/religious roles, \( R \). Other interesting cases arise when humans help plants and animals achieve their evolutionary functions, as when bringing back endangered species. In these latter cases, both internal and external agency contribute to achieving a species' original role.

As Table 9.1 illustrates, external agents have a physical structure, \( PS \), they adopt goals, \( G \), and they take initiating actions, \( IACT \), that trigger event sequences, \( E \). An agent's physical structure, \( PS \), is central to the functional affordance of a focal object, \( FO \). The functions that the focal object can play depend not only on its physical structure but also on the agent's physical structure (Gibson, 1979a, 1979b). Thus a ceiling can function as a resting place for a mosquito but not for a cat. An agent's goal, \( G \), is also central to what occurs functionally. For example, a hammer's function depends on whether an agent intends to use it for nailing, smashing, etc. Finally we include initiating actions, \( IACT \), in the physical environment, \( P \), because they belong to the full set of physical conditions required to begin the causal chain that realizes a function. All other resulting events will be
include in the subsequent event sequence, E. Together, a focal object, FO, a setting, S, and an optional external agent, EA, constitute a physical system that is sufficient to produce a functional outcome.

9.2.4 Event sequences (E)

Once the fully physical system, P, for achieving a function is present, full causal power is achieved, and an event sequence, E, is simulated (i.e., P → E). E includes two components. First, E contains the behaviors, B, of the focal object and of all relevant setting objects. Second, E concludes with the outcome, O. Typically B may include many behaviors of the focal and setting objects, with all these behaviors jointly contributing to O. If certain critical behaviors do not occur, the desired O may not follow.

When all of the causal conditions for achieving an entity’s historical role, R, reside in P, and when no competing causes exist, a sequence of behaviors, B, culminates in an outcome, O, that realizes R. When P takes some other form, or when competing causes exist, B and ultimately O may take other forms. For example, if an entity’s physical structure, PS, is altered or damaged in some way, O may depart from R (e.g., an animal unable to forage because of a damaged olfactory system). Similarly, when organisms learn, they may acquire new goals. G, from settings, S, that cause their behaviors to diverge from evolutionary roles (e.g., when a dog learns to chase cars). Finally, when an agent, A, has a goal, G, that differs from an artifact’s historical role, R, the outcome, O may diverge from R. For example, if an agent wants to hold some paper down with a hammer, a non-standard function of the hammer may be realized. Thus R is only realized when all its conditions are realized in P, and no competing causes exist.

9.3 Causal Chains in HIPE

The HIPE theory assumes that people typically have knowledge about history, intentional perspective, the physical environment, and events for a given entity. By no means, however, does HIPE assume that people have complete knowledge in any of these domains. Indeed people may often lack knowledge of some components in Table 9.1, and those they do know may be represented partially or incorrectly. We merely propose that people’s knowledge about function typically follows the structure in Table 9.1, and that when they lack knowledge about specific components, their meta-knowledge specifies that such knowledge probably exists and may be relevant.

As discussed earlier, we make several other assumptions about how people represent functions. On a given occasion, people only access a subset of the relevant HIPE knowledge. To represent the subset retrieved, they reenact it in a multi-modal simulation. A causal chain underlies the simulated event sequence, producing transitions between states of the simulation.

Finally we make two assumptions about the properties of causal chains. First, an individual relation, X → Y, is causal when X and Y are correlated, when the expected temporal relation holds (Y does not precede X), and when the expected kind of intervention is supported (manipulating the value of X changes the value of Y). Second, when multiple causes produce an effect, the effect is some as yet unspecified function of the joint causes. In (4), for example, we assume that C is some function of R and EGR. Each cause plays a role, but its size and relation to the other cause may be unknown.

9.3.1 Flexibility and falsifiability

As will be seen shortly, many causal chains can be constructed from the HIPE knowledge for an entity. Rather than only thinking about the entity’s function in a single way, people can think about it in many different ways, depending on the circumstances. The HIPE theory is designed to capture this flexibility. On different occasions, different subsets of HIPE knowledge are accessed and configured into different causal chains, each representing one particular belief about the entity’s function.

One concern might be that this theory is so powerful as to be unfalsifiable. Perhaps it can represent any proposed hypothesis about function. We believe that HIPE is falsifiable in at least three ways. First, it predicts that function is a complex relational structure distributed across modalities. If the representation of function turns out to be atomistic, unimodal, or amodal, HIPE would be falsified. Second, HIPE predicts that knowledge about function is flexible, not rigid. If knowledge of function turns out to be rigid, HIPE would be rejected. Because previous theories have not proposed that function is flexible (to our knowledge), this strikes us as non-obvious. Finally, HIPE predicts that representations of function are drawn from four types of conceptual knowledge (H, I, P, and E), and that the componential structure in Table 9.1 captures the central content of this knowledge. HIPE is falsified if general types of knowledge must be added or deleted, or if the componential structure for a type of knowledge must be modified significantly.

9.3.2 Causal initiation

As discussed earlier, we believe that intentional perspective, I, plays a central role in accessing specific subsets of HIPE knowledge. In general, I determines the specific functional sense, Fn, simulated on a given occasion for an entity. Thus:

\[ I \rightarrow Fn \]  

\[^{3}\text{A related issue is whether principled constraints govern the functional representations possible within HIPE. Clearly not every possible combination of HIPE’s components constitutes a meaningful representation. At this time, specific constraints on this process remain to be developed.} \]
where $F_n$ is some configuration of components from the $H$, $P$, and $E$ domains. As Table 9.1 illustrates, $I$ in (5) can be decomposed to yield:

$$MP \rightarrow POV \rightarrow F_n \quad (6)$$

Thus an agent’s meta-cognitive purpose and point of view produce the functional sense simulated for an entity on a given occasion. In general, $I$ can be viewed as an operator that, first, establishes a $MP$ and a $POV$, which in turn operate on knowledge to produce a particular $F_n$. When the same $I$ is applied to knowledge of different entities, a different $F_n$ results for each entity. Conversely, when different $I$s are applied to knowledge of the same entity, a different $F_n$ results for each $I$.

In many situations, an agent’s intentional perspective may arise internally as goals are generated in a top-down manner. For example, an agent who likes music may create the goal of attending a concert, which is then realized in a functional event, $F_n$. In other situations, however, an agent’s intentional perspective may be triggered by a state of the physical environment, $P$, or by an event sequence, $E$, occurring in it—the agent may not have the goal beforehand. Under these conditions, the causal sequence takes one of the following forms:

$$P \rightarrow I \rightarrow F_n$$
$$E \rightarrow I \rightarrow F_n \quad (7)$$

Analogous to the decomposition of (5) into (6), $P$, $E$, and $I$ in (7) could be expanded using more specific components from Table 9.1. Depending on the situation, different aspects of $P$ or $E$ might trigger the resultant intentional perspective, $I$, to represent a particular functional sense, $F_n$.

For the remainder of this section, we delete intentional perspective from most causal chains. By simplifying them in this manner, the relevant components become more salient. Of course, an intentional perspective is always present, and it always plays a central role in shaping causal chains.

9.3.3 Causal level

As the decomposition of (5) into (6) illustrates, causal chains can be represented at different levels of specificity. It is an open question whether people represent causal chains at multiple levels or just one. Regardless, representing these chains at different levels is useful notationally for theoretical purposes.

For example, we can distinguish different theories of function most directly at the general level. Consider affordance theories, which propose that function depends on both the physical structure of an entity and the physical structure of the organism using the entity (Gibson, 1979a, 1979b). We can represent this general view as:

$$P \rightarrow E \quad (8)$$

$P$ includes the physical structures of the focal object and the agent, which determine the functional events, $E$, that follow. In contrast, historical views propose that the physical structure of an entity depends on its history (e.g. Bloom, 1996, 1998; Gelman and Bloom, 2000; Matan and Carey, 2001; Prasada, 1999a). We can represent the design stance as:

$$H \rightarrow P \quad (9)$$

Here an entity’s history, $H$, produces a physical structure, $P$, that achieves the entity’s historically intended role. At this general level, it is easy to see the difference between these theories. Whereas the affordance view predicts that people ignore history when assessing function, the historical view predicts that people take history into account. Similarly, (8) and (9) illustrate how physical structure is a cause in affordance theories but an effect in historical theories.

When people actually reason about function, they may reason at a level that is more specific than the level in (8) and (9). For example, someone reasoning about affordances at a more specific level might decompose (8), $P \rightarrow E$, into the following causal chains:

- **Geological kinds**
  $$FO(PS) \rightarrow B \rightarrow O$$
  $$S \rightarrow B \rightarrow O$$

- **Living things**
  $$FO(PS, G) \rightarrow B \rightarrow O$$
  $$S \rightarrow B \rightarrow O$$

- **Artifacts**
  $$FO(PS)$$
  $$S \rightarrow B \rightarrow O$$

For a geological kind, its physical structure and setting are the cause of its function. For a living thing, its physical structure, internal goals, and setting constitute the critical cause. For an artifact, its physical structure and setting, together with an external agent, produce its function. These specific causal chains capture the prediction that people believe different configurations of physical components cause the functions of artifacts, living things, and geological kinds. As (10) illustrates, constructing causal chains in the HIPE framework brings out the functional differences between different types of concepts.

*For the design stance, an object’s intended role would presumably be conceptualized in its designer’s mind as an affordance, namely, $P \rightarrow E$. Once the object exists and has the required structure, it can produce the desired event. Nevertheless the focus of the design stance is on designing a physical object that eventually achieves a desired affordance, not on instances of the affordance being realized.*
We can similarly decompose the causal chain in (9), $H \rightarrow P$, for the historical perspective into more specific causal chains:

**Geological kinds**

$$R \rightarrow C \rightarrow FO(PS)$$

**Living things**

$$R \rightarrow C \rightarrow FO(PS, G)$$

(11)

**Artifacts**

$$R \rightarrow M \rightarrow FO(PS)$$

$$IV \rightarrow S \rightarrow B \rightarrow O$$

As (11) illustrates, people might conclude that the physical structure of a geological kind is the result of its ecological role, a long-term geological process, and a more recent creation process. People might reason similarly about living things, but conclude further that a living thing’s internal goals—not just its physical structure—reflect its history. Finally people might reason that an artifact's physical structure reflects its intended role, invention, and manufacturing history.

Although theories differ on whether affordances or history are central to function, HIPE assumes that people reason in both ways. Depending on I, people represent the functional sense most relevant in the current situation.

### 9.3.4 Causal alignment

By assessing the alignment of components across HIPE domains, non-standard forms of function, including functional failure and ad hoc categories can be represented. Two components—outcomes and goals—appear particularly important for alignment. We address each in turn.

When a standard function is achieved successfully, the outcome, $O$, corresponds both to the historical role, $R$, and to any relevant goals, $G$. Consider the standard function of a hammer to pound in a nail. When a nail has been pounded in successfully, $O$ corresponds both to the external agent's goal, $G_{EA}$, and to the hammer’s historical role, $R$.\(^5\) Thus:

$$R \rightarrow M \rightarrow FO(PS)$$

$$IV \rightarrow S \rightarrow B \rightarrow O$$

(12)

Similarly consider one function ascribed to deer, namely, to consume vegetation. When a deer consumes vegetation successfully, $O$ corresponds both to the deer’s internal goal, $G_{FO}$, and to its historical role, $R$:

$$R \rightarrow C \rightarrow FO(PS, G) \rightarrow B \rightarrow O$$

$$IV \rightarrow S \rightarrow B \rightarrow O$$

$$G_{FO} \sim R$$

(13)

As these examples illustrate, HIPE predicts that people assess whether $O \sim G \sim R$ to determine whether an entity’s standard function has been achieved successfully. HIPE can similarly represent when attempts to achieve standard functions fail. Imagine that a hammer's wooden handle has shattered, such that the hammer can no longer pound in nails effectively. This state of affairs can be represented as follows:\(^6\)

$$R \rightarrow M \rightarrow FO(PS)$$

$$IV \rightarrow S \rightarrow B \rightarrow O$$

$$EA(PS, G, IACT)$$

$$G_{EA} \sim R$$

(14)

As (14) states, the outcome, $O$, does not correspond to $G_{EA}$ or $R$, presumably because the focal object's physical structure, $PS_{FO}$, is not as expected. Because of this alignment failure, an agent would conclude that the hammer's standard function had not been achieved successfully. As (12), (13), and (14) illustrate, causal chains in HIPE can capture both success and failure in achieving standard functions.

HIPE can also represent non-standard functions through the non-alignment of goals, $G$, with roles, $R$. Of interest here are ad hoc categories (Barsalou, 1983, 1985, 1991). For example, a hammer might be used as a paper weight such that:

$$R \rightarrow M \rightarrow FO(PS)$$

$$IV \rightarrow S \rightarrow B \rightarrow O$$

$$EA(PS, G, IACT)$$

$$G_{EA} \not\sim R$$

(15)

$PS_{FO}$ Finally, $\sim$ will indicate correspondence between roles, goals, and outcomes, whereas $\not\sim$ will indicate lack of correspondence.

\(^5\) Because $G$ occurs twice in the notation, subscripts will distinguish the goals of external agents, $G_{EA}$, from the goals of focal objects, $G_{FO}$, as needed. Similarly subscripts will distinguish the physical structure of external agents, $PS_{EA}$, from the physical structure of focal objects, $PS_{FO}$.

\(^6\) We will use italics to indicate that components in causal chains take unusual values and thereby produce atypical outcomes. Thus, $FO(PS)$ is in italics for (14), as is $G_{EA}$ for (15), $G_{FO}$ for (16), and both $G_{EA}$ and $S$ for (17)
In (15), the external agent, $EA$, has a goal for using the hammer, $G_{EA}$, that differs from its standard role, $R$. As a result, the outcome, $O$, corresponds to the non-standard goal but not to the standard role, assuming that all of the conditions for achieving the non-standard outcome are present.

A similar causal chain could be constructed for a living thing that performs a non-standard function:

$$
\begin{align*}
R & \rightarrow C \rightarrow FO(PS, G) \rightarrow B \rightarrow O \quad O \sim G_{sa} \not\sim R \\
EGR & \rightarrow S & B & \rightarrow O & O \sim G_{sa} \not\sim R
\end{align*}
$$

(16)

For example, if a dog chases a car, its internal goal, $G_{FO}$, no longer corresponds to its historical role, $R$. Again the outcome, $O$, corresponds to the non-standard goal when the conditions for achieving it are met.

HIPE can also represent cases where a non-standard goal fails. For example, imagine that a hammer fails as a paperweight due to high winds. This failure can be captured as:

$$
\begin{align*}
R & \rightarrow M \rightarrow FO(PS) & S & \rightarrow B \rightarrow O & O \not\sim G_{sa} \not\sim R \\
IV & \rightarrow S & B & \rightarrow O & O \not\sim G_{sa} \not\sim R
\end{align*}
$$

(17)

As (17) illustrates, the hammer plays a non-standard role, $G_{EA} \not\sim R$, and the outcome fails to achieve it, $O \not\sim G_{EA}$, due to an atypical property of the setting, $S$.

Finally, the frequent pursuit of a non-standard goal establishes an unusual use history, $UH$, in an artifact's history, $H$. For example, a hammer only ever used as a paperweight establishes a use history that displaces its standard role, $R$. On encountering this particular hammer, $UH$ may trigger its non-standard role through the external agent’s goal, $G_{EA}$:

$$
\begin{align*}
R & \rightarrow M \rightarrow PS_{sa} & S & \rightarrow PS_{sa} \rightarrow B \rightarrow O \quad O \sim G_{sa} \not\sim R \\
IV & \rightarrow S & B & \rightarrow O & O \sim G_{sa} \not\sim R
\end{align*}
$$

(18)

When $UH$ is stronger than $R$, $IV$, and $M$, the non-standard goal occurs in $B$ and $O$. As (18) illustrates, complex HIPE components such as $EA(PS, G, IACT)$ can be broken out into their more specific sub-components as needed. Breaking out $EA(PS, G, IACT)$ allows showing that $UH$ affects $G_{EA}$ specifically, not $EA$ as a whole. This further illustrates HIPE’s ability to represent causal chains at multiple levels of specificity (compare 8, 10, and 18).

In general, $UH$ for artifacts and $LH$ for natural kinds may establish entrenched senses of function that compete with standard roles, $R$. As a result, $UH$ and $LH$ bias the intentional perspectives, $I$, that determine the functional senses, $Fn$, simulated for entities:

$$
\begin{align*}
UH & \rightarrow I \rightarrow Fn \\
LH & \rightarrow I \rightarrow Fn
\end{align*}
$$

(19)

As described in the section on causal initiation, other factors determine $I$ as well, such as the agent’s goal and the current setting (see (7)). Nevertheless the personal histories in $UH$ and $LH$ may often play a central role, thereby producing variability in how people conceptualize function (analogous to the role of personal history in Barsalou, 1987, 1989, 1993).

9.4 Applications

We have offered a theory of function and a notation for representing it. A key question is what can this theory do? Is it just an armchair theory, or is it useful in generating predictions and explaining findings? To address this question, we offer examples of how we have found HIPE useful in our own work.

First, HIPE offers a novel account of function. Rather than being a simple unanalyzed property, an entity’s function is a complex relational construct, drawing on many modalities for its content, structured by causal chains. Furthermore, an entity’s function has many senses, not just one, depending on an agent’s current goal, setting, and personal history. HIPE also provides hypotheses about the different causal chains underlying the functions of artifacts, living things, and geological kinds (see (10)).

Second, HIPE generates useful predictions. Consider again the affordance account of artifact function from (10):

$$
\begin{align*}
FO(PS) & \rightarrow B \rightarrow O \\
EA(PS, G, IACT) & \rightarrow S \rightarrow B \rightarrow O
\end{align*}
$$

(20)

As (20) states, the functional outcome, $O$, cannot occur until all of the conditions in the physical environment, $P$, are present, namely, $FO(PS)$, $S$, and $EA(PS, G, IACT)$. Once these conditions exist, they produce the relevant behaviors, $B$, followed by $O$. Chaigneau et al. (2004) tested this prediction by manipulating the
information about the physical environment, \( P \), that participants received while trying to understand the function of a novel object. When participants received only the physical structure of the focal object, \( PS_{FO} \), they were poor at specifying the object's function. When participants further received the relevant setting, \( S \), along with \( PS_{FO} \), their ability to specify the focal object's function improved but was far from perfect. Only when the agent's action, \( IACT \), was presented along with \( S \) and \( PS_{FO} \) were participants able to fully specify the object's function. These results support HIPE's central assumption that a complex configuration of entities and events underlies people's understanding of a functional event. Only when this entire configuration exists does understanding become complete.

As described earlier, another of HIPE's predictions is that the function of an entity has many senses, not just one. Juxtaposing Chaigueau et al.’s results with others in the literature demonstrates this multiplicity. As just described, Chaigueau et al. found that participants could fully understand an object's function based solely on the physical environment, \( P \). Participants did not need to know the object’s history, \( H \), to have an adequate understanding (they learned nothing about history in these experiments). In contrast, a number of researchers have found that an object's function does depend on its history (e.g. Bloom, 1996, 1998; Gelman and Bloom, 2000; Matan and Carey, 2001; Prasada, 1999a). This apparently conflicting pattern of results is consistent with HIPE's prediction that function takes different senses. On some occasions, participants’ intentional perspective, \( I \), orients them towards an object’s physical affordances; on other occasions, a different \( I \), orients participants towards the object's history.

Chaigueau et al.'s finding that \( H \) was irrelevant when \( P \) was fully specified illustrates the distance principle of causal chains (cf. Pearl, 1988). In the causal chain, \( A \rightarrow B \rightarrow C \), cause \( A \) is irrelevant to effect \( C \) because \( B \)'s closeness to \( C \) is sufficient for causing \( C \). Consider how the distance principle applies to the causal chain that results from combining (8) and (9):

\[
H \rightarrow P \rightarrow E
\]  

(21)

Once \( P \) is fixed in (21), \( H \) becomes distant and should matter little, which is what Chaigueau et al. observed.

Besides producing novel predictions, HIPE explains and integrates findings. Consider Gelman and Bloom's (2000) finding that history is central to function. In their work, children were told that a makeshift object was created either intentionally or accidentally to serve a function. For example, a newspaper was formed into a hat intentionally by an agent, or was formed accidentally by a car running over the newspaper. Under these conditions, children thought that 'hat' better named the intentional object than the accidental one. Note, however, that the children never received other information that HIPE specifies as central to function, such as the setting, actions, and events involved in actually wearing the hat. In recent work, Chaigueau (2002) added these additional factors into situations like these and found that intentional vs. accidental history became a relatively minor factor (see also Chaigueau, Barsalou and Sloman, 2004).

HIPE explains these divergent results. In Gelman and Bloom's study, children only received history, \( H \), and physical structure, \( P \). As a result, they had the requisite conceptual material to develop causal chains like those in (9) and (11). In contrast, Chaigueau’s participants received much more knowledge about \( P \) and \( E \), thereby providing them with the critical elements for constructing affordance chains like those in (8) and (10). Under these latter conditions, history became distant from the functional outcome, thereby decreasing in importance (Pearl, 1988).

HIPE similarly explains the importance of history in Matan and Carey (2001). In these experiments, participants were told that a makeshift object was constructed to serve a particular function (e.g. a teapot), but were told little about the object's physical structure. Later, participants were told that the object actually performed some other function (e.g. a watering can). Under these conditions, participants believed that 'teapot' was a better name for the object than 'watering can'. HIPE explains the importance of history here in terms of alignment, namely, 'teapot' maximizes the correspondence between \( R \), \( GF_A \), and \( O \), whereas 'watering can' does not (compare (12) vs. (16)). When history is salient, participants like to maximize alignment. HIPE further predicts, however, that if the object's history of use, \( UH \), became biased over time towards the watering can, participants might come to prefer naming it with 'watering can' (see (18)). Finally HIPE further predicts that if participants receive more information about the object's physical structure that affords using it as a watering can, then history might become distant and play less of a role. When Chaigueau's (2002) participants received more complete knowledge about \( PS_{FO} \) in situations like these, history's role diminished considerably, supporting this prediction.

In summary, HIPE offers a detailed conceptual account of function and the various senses it takes. It also illustrates the power of expressing knowledge as causal graphs. As just illustrated, HIPE provides a useful framework for explaining current findings, and for resolving apparent discrepancies between them. HIPE may require significant revision in the face of future data and further theoretical considerations. Hopefully, however, HIPE will provide useful insights into the construct of function, and into the literature addressing it. We would find ourselves chagrined to discover that this theory of function was all hype.
References
Chaigneau, S.E. (2002) *Studies in the conceptual structure of object function*. Doctoral dissertation, Department of Psychology, Emory University, Atlanta, GA.
Gelman, S.A., & Bloom, P. (2000). Young children are sensitive to how an object was created when deciding what to name it. *Cognition, 76*, 91-103.